knowledge of the telluric spectrum. The author must be glad that his laborious observations have led to such tangible results.

A METHOD OF MEASURING ATMOSPHERIC DISPERSION.—At the Paris Academy on February 16, M. Prosper Henry described a novel method for determining atmospheric dispersion and its variation with the wave-length of the light observed. A *reseau*, formed of Bristol board perforated very regularly with holes about 1 millimetre apart, was placed in front of the object-glass of a telescope as a diaphragm. When a luminous point, not affected by atmospheric refraction, is observed through this arrangement, a double series of spectra are seen besides the central image of the point. M. Henry shows that by knowing the zenith distance of a star, and the size of the meshes of the *reseau*, the value of atmospheric dispersion (D) may be found by determining the angular distance of any particular part of the spectrum from the central luminous point. A large number of stars have been observed at Paris Observatory, and from them D has been found to be 0″·723 for eye observations, whilst the value 0″·729 has been deduced from photographs. The most probable value may therefore be taken as 0″·726. If the wave-length of the maximum light intensity of the spectrum be taken as 575 μμ, and the average amount of atmospheric refraction (A) for an object having a zenith distance of 45° be 58″·22, it is found that

$$A = 56''\cdot55 + \frac{0''\cdot726}{\lambda^{\frac{3}{2}}}.$$

This formula gives the following values for light of different wave-lengths:—

Wave-length.	Average atmospheric refraction.
μμ	″
700	57·79
600	58·11
575 (maximum light intensity)	58·22
500	58·66
430 (maximum chemical intensity) ...	59·13
400	59·42

It will be seen that the most intense chemical rays give a value of A 0″·91 higher than that furnished by light of maximum luminosity.

The comparison of the different dispersive effects of the atmosphere on light of different wave-lengths indicates that, in the latitude of Paris, the green portion of the solar spectrum ought to be visible about a second after the disappearance of the yellow. This explains the phenomena noted by the late M. Thollon and other observers of the telluric spectrum. It is found that, in the majority of cases, the last light visible at sunset is in the blue part of the spectrum; this green or blue light is a limit of the visible spectrum when the sun is on the horizon, the more refrangible rays being absorbed by the atmosphere.

WOLF'S "RELATIVE NUMBERS" FOR 1890.—*Comptes rendus* for February 16 contain the "relative numbers" obtained by Wolf from a reduction, by the usual method, of the solar observations made at various Observatories in 1890. The following table shows the mean values (r) obtained for each month in the year, the mean variations (v) in magnetic declination observed at Milan, and the increments (Δr, Δv) that these quantities have received since the corresponding epochs of 1889:—

	Solar Observations.		Magnetic Observations.	
	r	Δr	v	Δv
Jan. ...	5·3	+ 4·5	3·02	+1·27
Feb. ...	0 6	− 7·9	4·81	+0·82
March ...	5·1	− 1·9	7·49	+1·32
April ...	1·6	− 2·7	8·68	−0·17
May ...	4·8	+ 2·4	7·70	−0·49
June ...	1·3	− 5·1	8·84	−0·02
July ...	11·6	+ 1·9	8·57	+0·32
Aug. ...	8·5	−12·1	8·00	−0·99
Sept. ...	17·2	+ 0·7	7·10	+0·26
Oct. ...	11·2	+ 9·1	8·72	+2·62
Nov. ...	9·6	+ 9·4	3·10	+0·55
Dec. ...	7·8	+ 1·1	2·54	+0·58
Means	7·1	+ 0·8	6·55	+0·51

NEW ASTEROIDS.—M. Charlois discovered (303) on February 11, Prof. Millosevitch (304) on the following day, and Dr. Palisa (305) on February 14.

THE BRITISH MOSSES.[1]

II.

LEAVES.—When we examine the leaves of mosses and compare them with the more familiar forms presented to us by the phanerogams, we find ourselves in a new world, and the interest with which we view them is increased when we remember that, according to the view usually accepted, they are, so to speak, a unique phenomenon: they are not the descendants of any earlier leaves nor the ancestors of any later ones; they appear thus once, as it were, in the history of the vegetable kingdom, and advance no further. They possess something of the charm which an *ἅπαξ λεγόμενον* exercises over the mind of a philologist.

We may first note what they are not. They are never opposite, never whorled, never on leaf-stalks, never truly veined, never lobed or compound, never furnished with epidermis or stomata.

When we turn to consider affirmatively what moss leaves are, we find them in some cases characterized by an extreme simplicity of form. They are single plates of similar cells without midribs, without veins, and without border; again, they stand in immediate connection with the atmosphere, absorbing moisture from it when moist, and shrinking and shrivelling when the air is dry. In some cases they are characterized by a marked difference in the form of the cells in the different parts of the leaf, and again in other cases by the unequal distribution of chlorophyll; in other cases we come across strange forms, the like of which we hardly know in the phanerogams: such are the thick border and double rows of teeth in some of the genus Mnium; the parallel plates in Polytrichum; and, stranger still, the third flange of the leaf in Fissidens, the true homology of which has proved a *crux* to bryologists.

In some cases the leaf is produced into a long thread or beak devoid of chlorophyll, and often with indented or toothed edges. This structure is found chiefly in mosses living on stones and rocks and in dry situations, such as Grimmia and Racomitrium, and the presence of these long white threads or beaks gives a grey tint to the whole moss; and in places where the moss is predominant (as, for instance, some parts of Dartmoor and North Wales, where Racomitrium abounds) a grey tint to the whole landscape. These long hairs and prominences, especially when armed with lateral teeth, no doubt retain the moisture which is necessary not only for the vegetative life of the moss, but also for the process of reproduction by archegonia and antheridia; hence it probably is that this form of leaf prevails in mosses living in dry situations, just as the thick leaves of succulent plants are found in similar situations.

The Roots or Rhizoids of the mosses are distinguished by the minuteness of their growing ends, by their pliancy, and by the presence on their exteriors of a balsamic or glutinous deposit. To these points of structure they owe their capacity to insinuate themselves into the minutest crevices of rock, to get, for instance, amongst the particles of the oolites, and also to fix themselves in the shifting sands of the sea-coast, and by so fixing themselves to give fixity in return to the sand, and so tend to produce the sand-dunes in many parts of the coast. At some parts of the Northumbrian coast the *Racomitrium canescens* may be found buried deep in the sand, from which it can scarcely be detached, and in like manner the sand-dunes of Holland and the west of France have in many places been fixed by mosses. The forests of firs on the North Sea and the Bay of Biscay thus owe their origin to humble mosses.

Sphagnaceæ.—Vast tracts of land in this country and throughout Northern Europe and America are covered with plants of this group, and large tracts which are now fertile agricultural land, where they have entirely ceased to grow, have in former times been occupied by them. The bogs of Ireland, which are mainly constituted of turf moss, were computed in 1819 by the Bog Commissioners to occupy 2,830,000 acres. No moss has probably ever, at least in the present state of the globe, played so large a part as the Sphagnum or peat moss.

Structure.—It is to the peculiar structure of the peat moss that this great part on the theatre of the globe is to be attributed.

Leaves.—In the young leaves the component cells are all alike; then by a differential growth we are presented with square cells surrounded by four narrow and oblong ones; then chlorophyll forms in these narrow cells, but is absent from the square cells; from these the contents disappear, and water or water-like fluid occupies the whole cell; subsequently annular and spiral threads develop on the walls of the square cells. The intimate structure of the leaf thus enables it to absorb great quantities of water.

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[1] The substance (with omissions and additions) of a Discourse by the Right Hon. Lord Justice Fry, delivered at the Royal Institution, January 23, 1891. Continued from p. 382.

But again, the shape of the leaves is in many species adapted to the retention of water. By a retardation of the lateral as compared with the mesial growth, the leaf assumes a boat shape. Often the edges of the leaves are turned over; the leaf thus affords means of holding water. Again, the lateral branches grow in groups from the stem, and some of these branches are generally pendent, and in close proximity to the stem, so that an immense capillary attraction is exerted by them.

Again, the *stem* itself is surrounded or rather is more than half occupied by large water-holding cells, and pitchers of a very peculiar form.

Again, the mode of growth of the plant, abandoning its moorings on the soil and throwing out roots into the water, and growing successively year after year, enables it not only to attain great growth, but also, when the occasion demands, to keep pace with the rise of the water in which it may be growing, "the individual thus becoming," it has been said, "in a manner immortal, and supplying a perpetual fund of decomposing vegetable matter."[1]

Physical Results from Structure.—The result of these peculiarities is that the entire plant of any species of Sphagnum is a perfect sponge. When dry it is capable (as may easily be found by experiment) of rapidly absorbing moisture, and carrying it upwards through the plant; and when growing in vast beds it acts thus on a great scale. Everyone who knows Scotland must know how on many a steep mountain-side, or on the bottom and sides of a gorge, these beds will hold up a great body of water against the force of gravity; and again, the Irish bogs are described as often ascending from the edges towards the interior, sometimes by a gradual, and sometimes by a sudden ascent, so that at times the bog is so high that it reaches the height of the church steeples of the adjoining country, without any rising ground intervening.

These peculiarities in the structure of Sphagnum have produced considerable physical effects.

(1) Everyone knows the different effects of rain falling on a land of bare rock or sand, like the Sinaitic desert, and on a porous soil; in the one case it produces a freshet or a flood, that leaves no trace behind; in the other it is held for a while in suspense, and only gradually passes into the streams. The glaciers and the Sphagnum beds of the mountains of Europe alike act as compensation reservoirs—receive large quantities of moisture as it falls, and retain it till the drier season comes, when it gradually passes away in part; but for these reservoirs, many of the rivers would exhibit a far greater shrinkage in summer and autumn than is now the case.

But (2) the Sphagnum beds have become peat, and have gradually filled up the ancient lakes and morasses, and turned water into dry land. It is true that peat appears under some circumstances to be formed by other vegetables than Sphagnum, and in all cases it has probably some other plants or roots growing amongst it. Mr. Darwin tells us that in Terra del Fuego and the Chonos Archipelago, peat is formed by two phanerogamous plants, of which one at least seems endowed with an immortality something like that of the Sphagnum; and the peat of the fens of Lincolnshire is formed mainly of *Hypnum fluitans*. But Sphagnum appears to be the main constituent of peat in Ireland, Scotland, and, so far as my researches have gone, in England; the peculiar spiral threads of the cells of the Sphagnum leaf being easily detected in the peat so long as it retains traces of its organic origin.

Ancient Forests.—The peat mosses, and the sea-shores of our islands and of the adjoining mainland, reveal, as it is very well known, traces of ancient forests. Many parts of England, nearly all the mainland of Scotland, the Hebrides, the Orkneys, and the Shetlands, Ireland, and Denmark, the shores of both sides of the English Channel, Normandy, Brittany, the Channel Islands, and Holland, and the shores of Norway, all bear evidence to the presence of these primæval forests; and what is more, to the successive existence of forests, each in succession living above the buried remains of the earlier ones.

The following table will show the order of succession in the different species of trees in some of the places where this has been observed, the braces representing the co-existence of the trees:—

Island of Lewes.	England.	Scotland.	Denmark.	Danes Moor, near Macclesfield.
1. Oak.	1. Oak. Scotch fir	1. Oak. Scotch fir	1. Scotch fir	1. Scotch fir.
2. Elder.			2. Oak.	2. Larch.
3. Birch.	2. Birch. Hazel.	2. Birch.	3. Birch.	3. Oak.
4. Scotch fir.		3. Hazel.		4. Birch.
	3. Alder.	4. Alder.		5. Hazel.
		5. Willow.		6. Alder.
		6. Ash.		7. Willow.
		7. Juniper.		

What is the cause of the disappearance of these ancient forests one after the other? To this question various answers have been proposed.

The Romans, it has been suggested, in their inroads, cut ways through the forests and laid waste the land. But, wide as was the spread of the wings of the Roman eagle, the phenomenon in question is of far wider extension. They never conquered Denmark, or Norway, or Ireland, or the islands of Scotland: in Scotland, and even in England, their operations could never have covered the whole country; and as regards some of our peat mosses, we know that they must have existed long before the Roman invasion; for at least on the borders of Sedgmoor we have traces of their using peat for fuel as it is used there at the present day.

Still humbler agents have been invoked, in the supposition that the beaver and other rodents were the authors of the destruction of the forests. So far as I can judge, the cause suggested seems inadequate to the effect.

Again, changes in climate have been suggested. But, although there may be some evidence from the succession of the trees of a gradual amelioration in the climate, we know of no evidence of changes of so sudden and violent a character as would destroy the existing forests over large areas. Moreover, with few exceptions, the trees of the destroyed forests are such as are now found wild, or will grow easily in the spots where they lie buried.

The overthrow by storms has, again, been suggested as the cause of this wholesale destruction; and the fact that in some of the peat bogs of the west of Scotland the trees that have fallen lie to the north or north-east, and in some of those in Holland to the south-east, in the direction of the prevailing winds in those countries respectively, affords some reason to believe that wind has given the *coup de grâce* to the dying trees, and determined the direction of their fall. But it is much more likely that this was the work of the wind, than that successive forests should have been swept from the face of vast tracts of Europe by the agency of wind alone. Moreover, in some cases the trunks as well as the bases and roots of the trees are found standing or buried in the bogs.

Allowing that some or all of these agencies may have had their part in the destruction of the forests, I believe that the growth of Sphagnum has been the greatest factor in the work of destruction. "To the chilling effect of the wet bog mosses in their upward growth must be attributed," says Mr. James Geikie, "the overthrow of by far the greater portion of the buried timber in our peat bogs" (Trans. Roy. Soc. Edin., xxiv. 380).

In a letter written by Lord Cromarty, in 1710, on peat mosses, and published in the twenty-seventh volume of the Philosophical Transactions, we get a curious account of the swallowing up of a forest by a peat bog. In 1651 the Earl saw, in the parish of Lochburn (or, as Walker says, at Loch Broom, in West Ross), a plain with fir-trees standing on it, all without bark, and dead. Of the cause of their death he says nothing. Fifteen years after, he found the whole place a peat moss or "fog," the trees swallowed up, and the moss so deep that in attempting to walk on it he sank in it up to his armpits.

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[1] Macculock, "Western Islands," p. 130.

But, it will be said, assuming that this may be the case with one growth of forest, how about the successive destruction of successive forests? The answer is, I believe, to be found in the curious change which peat undergoes, and which converts it from a substance highly absorbent of water into one impervious to it.

The section exposed by a peat-cutting in, I believe, almost all cases exhibits two kinds of peat, the one known variously as red peat—or red bog, or fibrous bog, or in Somersetshire as white turf—which lies at the top, and the other, is a black peat, which lies at the bottom. The red peat retains visible traces of the Sphagnum of which it is mainly composed, and is highly absorbent of moisture; whilst the black peat has lost all, or nearly all, traces of the minute structure of the cells, and is not only unabsorbent of moisture, but is impervious to it. In fact, it constitutes an insoluble substance which is said to be scarcely subject to decay, so that it is used in Holland for the foundations of houses, and is found unchanged after ages, and when the buildings have fallen into decay. It is even said to have remained unchanged after three months' boiling in a steam-engine boiler. The broad difference between these two kinds of peat may easily be ascertained by anyone who will subject the two kinds to the action of water.

If we now take a section of a peat bog, with a succession of forests one above another, the history of the formation will be, I believe, much as follows:—

(1) We must get a water-tight bottom—sometimes this is a stiff clay, sometimes a pan, *i.e.* a stratum of sand or gravel made into a solid plate by the infiltration of insoluble iron oxides, themselves often due to decaying vegetable matter. The necessity of this water-tight bottom is well shown by the fact that in places in the Irish bogs where a limestone subsoil occurs the bog becomes shallow and dry.

(2) If on this clay bottom or sandy or gravel soil a forest arises, it may flourish for a considerable period, until the natural drainage of the area is stopped, whether by the choking up of the course of the effluent stream, or from the aggregation of vegetable matter, or from the fall in the course of nature of the trunks of the trees themselves. Everyone who will consider how much care our rivers require in order to make them flow with regularity to the sea—who thinks, for instance, of the works in the Thames valley, or in the upper valleys of the Rhine—will see how often and how easily, in a country in the condition of nature, stagnant waters will arise. In the morass thus formed the Sphagnum has grown, years after years, and if it has not destroyed the old trees it has prevented the growth of young ones. The stools of the trees buried in the antiseptic waters of the Sphagnum pools have been preserved, whilst the fallen trunks have, except when preserved by the like circumstance, rotted, and added their remains to the peat which the Sphagnum has been producing. It has been observed in several places in Scotland, that the under side of fallen trees which would be protected from decay by the tannin of the Sphagnum is preserved, whilst the upper side has decayed or rotted away. Year by year the process of decay on the lower parts of the Sphagnum goes on until the water grows shallower and at last disappears, leaving the original morass choked and filled up by the Sphagnum and the plants which it has nourished. On the top of this soil have grown first the heathy and bog shrubs which first succeed the Sphagnum, and in time, as the soil has grown more solid, forest trees. This is our second forest. This first peat deposit, or the lower part of it at all events, having been turned into the black peat impervious to water, plays the same part in the next stage that the clay or pan did in the earlier stage. Again, the drainage of this second level gets stopped, and the forest bottom is loaded with stagnant water, the home of the Sphagnum; together, the water and the Sphagnum kill the forest trees, which share the fate of their predecessors. The same history is gone through again—the Sphagnum filling up the morass and turning the water into dry land until it supports the third forest, and so on to the end.

Decay of the Moss.—Then comes, however, in many cases a time when this process is arrested; the artificial drainage of the soil, or the physical position of the area, prevent the re-formation of a morass, and the Sphagnum dies away. So in many parts, if not universally, in Sedgmoor, in Somerset, it is almost impossible to gather a bit of Sphagnum, and the peat is well known to the peat diggers not to be reproduced. Here the regulated drainage of the level maintains the surface in the condition of meadows or agricultural land. But in many cases, especially on mountain sides or tops, when the Sphagnum has died, and the peat undergone its last change into black earth, a process of decay sets in under the influence of air and water. The water lies in holes or "hags," or flows in sluggish streams, wearing away the dead peat; and the surface of the soil is broken and uneven, small patches of green surface with a rough growth of sedge or grass being surrounded by wider spaces of black earth. Such is, or was some years ago, the condition of the peat on the top of Kinder Scout in Derbyshire; on the parts of Dartmoor around Cranmere Port; and such also it is described to be on many of the Lowland hills of Scotland.

Sedgmoor.—In some cases the peat mosses have been originally arms of the sea, and the peat has only grown after the exclusion of the salt water. Such appears to be the history of Sedgmoor, the great plain of Central Somerset. Northward it is bounded by the Mendips; eastward lies Glastonbury with its Tor or hill; westward the Bristol Channel. The plain is intersected by the low line of the Pouldon Hills, once a long level-backed island in the estuary and afterwards in the morass: and the way in which the villages lie and the moor is apportioned between them suggests that the Pouldon Hills and some other spots which slightly rise above the level of the moss were the original seats of population. Originally this whole area appears to have been open to the Bristol Channel, of which it formed a bay or recess. The Burtle beds are a marine deposit well seen at the slight elevation on which the village of Burtle stands, which have been traced in various places along the borders of the moor and indicate the old line of beach. A curious confirmation of this geological fact is afforded by the presence—the one on Shapwick Heath, and the other near Glastonbury—of two plants (the *Rumex maritimus* and the *Vicia lutea*) which are shore plants, but which have until recently maintained their places as remains of the ancient marine flora, showing the retreat of the sea. The *Vicia lutea* has, I believe, recently succumbed in this interesting locality to the British collector. The description of Glastonbury as the Isle of Avalon, and the account of the bringing of the body of King Arthur from Tintagel to its resting-place at Glastonbury, are confirmations from tradition of the same fact.

Then a change came over the district, apparently by the formation of a barrier of sand or mud along what is now the shore of the Bristol Channel, and in that way the sea-water was shut out, and a depressed region left with a mud surface; on this the Sphagnum grew, and gradually filled it up, but leaving down to historic times spaces of fresh water from which the Abbots of Glastonbury formed their great fishing lake at Meare, by the side of which they erected the beautiful manor house and fish house which still remain. When the Romans occupied this part of England, they not only used the Burtle beds for plastic clay, but used the peat in their kilns, and the remains of the road which they constructed across the moor are now found some 6 feet below the present surface. In like manner, the Glastonbury monks formed a pathway across the moor from their own abbey to Burtle, where they appear to have had a chapel which they served. It consists of alder trunks laid crosswise so as to form a kind of corduroy road. Its remains near Westhay are said to be about 12 feet below the surface. Now, as I have already said, the system of drainage is so complete that the peat, when once cut, is not reproduced (though the lower soil is said to have a remarkable power of expansion and rises often to the old level), and the Sphagnum is to be found rarely if at all on many parts of the moor.

To the intimate structury of the turf moss are thus to be attributed great results in the history of the world. To look at our own island alone, but for it the primæval forests that once covered the land might still be standing; but for it large tracts of land would still be lake and mere; but for it every freshet in a highland river would be a flood; without it we should have had no mosses on the confines of England and Scotland, and where would have been the border warfare and the border minstrelsy? where the moss hags in which the hunted Covenanters sought for shelter and freedom of worship? Or, to come southward, by force of its growth the broad meadows of Somerset have been built up, and the dark waters on which the mysterious barge bore the dead Arthur from Tintagel to Avalon have been turned into the green pastures of Glastonbury and Meare and the battle-field of Sedgmoor.